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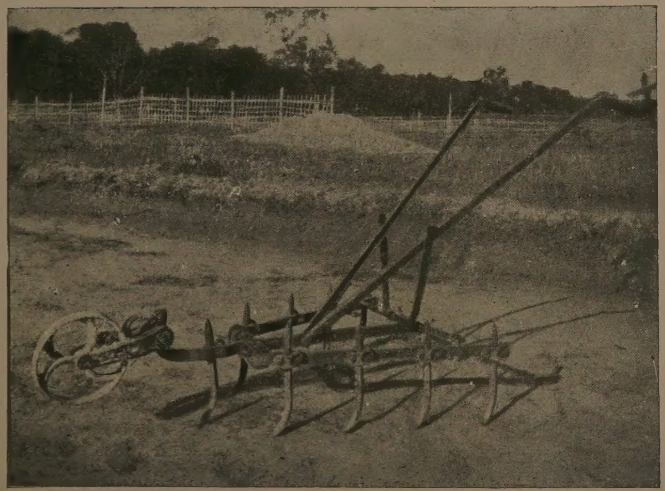
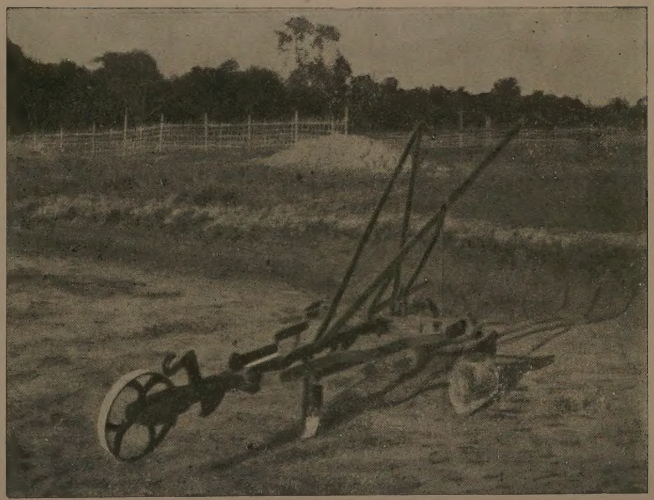




FIXED-TINE CULTIVATORS.

A NOTE ON MECHANICAL CULTIVATION

BY

P. H. CARPENTER, F.I.C., F.C.S.

The desire to use mechanical cultivation in tea gardens has resulted in trials of various types of cultivators and tractive power, but none has been found to be an outstanding success. There are, however, special cases where a greater amount of success has been obtained.

Some years ago it was realised that to obtain the requisite cultivation, at Borbhetta, would be extremely difficult owing to our entire dependence upon village labour who would be unlikely to come to work in sufficient numbers during the time of preparing the land and the planting of the rice and again at the harvest times. We therefore sought for a cultivator that could do some of the work and that could be used in young tea planted 4′ 6″ diagonal.

Various forms of harrows and cultivators were tried with the result that a five-toothed spring cultivator drawn by a buffalo was found to be the most satisfactory. The labour required was one man, and a boy to lead the buffalo. Cultivation is done at the rate of two acres per diem in every row in one direction only at the cost per acre of one rupee. The subsequent round of cultivation is put in, in a diagonal direction to the first one, and it is found practicable in young tea planted 4′ 6″ diagonal to use the cultivator in three directions. This ensures that all the ground, except that close to the bushes, is cultivated and it is a comparatively easy matter to keep the land clean of weeds. Hand weeding or forking needs to be done in the usual manner around the bushes.

With this type of machine it is necessary to work with clean soil ; that is to say, the cultivator is not capable of cleaning a piece of land that has a good growth of jungle on it. Starting with

clean land immediately after the deep hoe or first light hoe it affords a practical means for keeping the land clean with a corresponding benefit to the tea growing. On the light soil at Borbhetta a small bullock will pull the cultivator satisfactorily, but only 1½ acres per diem can be done. On heavier soils the small bullocks are unable to do the work and a buffalo is found to be more satisfactory, as it is able to exert a more steady pull. The cultivator at Borbhetta was required to cross the ordinary narrow subsidiary drains and the spring-tine cultivator, which is a wheelless machine with a low framework, was found to be satisfactory when three sledge runners were fixed below the frame. The tines are lifted out of the ground by means of the lever provided for the purpose immediately before crossing the drains and are again lowered after crossing the drains. This can be done without stopping the machine. We have found no other form of cultivator that will do this without unduly damaging the drain.

The cultivation done is not deep, being about three inches, but it appears to be sufficient for keeping down the jungle. It does not, however, deal in an altogether satisfactory manner with the deeper rooting grasses (like Sunn grass), as it does not cultivate deep enough to destroy the roots and it does not cut the straight-growing stems which are merely bent over by the cultivator but it becomes efficient if supplemented by a very little hoeing. The machine is cheap. The five-toothed harrow, as used by us, costs approximately Rs. 50.

Other types of cultivator with fixed tines were used and were found suitable in some cases but not of such general use as the spring-toothed machine as they were not able to cross the drains. In most cases the fixed-tine machines gave a somewhat deeper cultivation, but they require to work on more even land than spring-toothed machines. The machines have been used now for five years and have demonstrated that they can be employed successfully where labour is not available in sufficient quantity to carry out manual cultivation as it may be required to keep down the jungle growth.

TRIAL OF NITROGENOUS MANURES ON TEA, II*

BY

H. H. WILES, M.A.

This trial has now been in progress for four years on eighteen plots of 'Matelli' jat, planted one year from seed in 1916, collar-pruned in 1918, unpruned in 1919 and plucked from 1919 for initial fertility records until May of 1920, when the first dressing of manures, as given in the table hereunder, was applied.

The plots were left unmanured in 1921 in order to test the residual values of the manures applied in the previous year, but since then quantities of similar manures, equivalent to the original dressings, have been applied annually on all plots.

The bushes have been top-pruned to three-fingers of new wood each year and including 1920 up to date, and cultivation has been of the normal Tocklai type, namely, a deep hoe at a 15 null task in November or December, followed by six light hoes during the year, of which at least three are put in before the break of the monsoon.

The following table gives the average corrected yields over the whole course of the Experiment, together with percentages gain or loss in crop to date, for each type of manuring.

TABLE No. I.

MANURES.	CORRECTED YIELDS IN MDS. PUCCA TEA PER ACRE.					Percentage Increase or Decrease on Check.
	1920.	1921†.	1922.	1923.	Total 4 years.	
Check	9·58	7.7	7·97	8·67	33·92	.....
Nitrate of soda ...	10·55	8·1	9·40	12·00	40·05	18·07%
Green manure ...	10·01	8·4	8·45	10·22	37·08	9·31%
Oilcake	9·86	7·6	9·95	10·50	36·91	8·81%
Sulphate of ammonia...	10·24	7·5	8·09	10·04	35·87	5·75%
Sinews	9·55	7·5	7·76	9·00	33·81	-0·32%

NOTE :—* A previous article on this series of experiments appeared in the Quarterly Journal for 1921, Part I, pp 10-20.

NOTE :—† Unmanured to test residual effect of 1920 applications.

All plots, including the Check series, have received equal dressings of Phosphoric acid as bone-dust in 1922 and 1923, the phosphorus content of Oilcake and Sinews having been disregarded after 1920, in which year's applications it was, however, taken into account.

The Nitrogenous manures have been applied annually (except in 1921) at rates calculated to give 30 lbs. more nitrogen per acre on every series than that applied to the Check-plots (in bone-dust).

On studying these figures one immediately notices two points. The first is that the good yield originally produced by Nitrate of Soda in the first year has been well maintained throughout. The second is that no increase in crop during four years has occurred on the Sinews series.

A third point which stands out is the relatively good yield of the Green Manure plots in 1921, after being unmanured in that year, which, coupled with the good and steadily increasing yields of that and of the Oilcake series from then onwards, would appear to indicate a marked increase in fertility on these plots, which is no doubt partly due to the addition of organic matter to their soil and to a consequent improvement in tilth. In considering the yield from the Green Manure series in 1921 however, the lateness of the application of Green jungle in 1920 must be taken into account, and also the fact that, apart from the original unsuccessful attempt early in 1923, the green stuff applied to this series has never been grown on the plots themselves, but always on the adjacent land, so that the tea has not been adversely affected during the period of growth (see Cooper (1)).

It should be noted in this connection that the Oilcake applied in 1922 and 1923 was a much better and more readily available sample than the original application in 1920, containing under 10 per cent. oil in both the latter years as against over 15 per cent. oil in 1920.

The absence of residual effect from sulphate of ammonia in 1921 can be readily understood, as it is known to be very rapid

in action and, as noted by Cooper (1) in the previous article on this experiment, the yields from this series had already begun to fall off considerably before the end of the 1920 plucking season.

The continued low yield after a further dressing of manure in 1922 is, however, not so easy to interpret. It was possibly due in part to the fact that almost immediately after the manure was applied, which was during a rainless spell of 15 days in the middle of April, over six inches of rain fell on five consecutive days, the soil moisture rising from 15·76% to 21% in that period (see Table II). These conditions must, however, have adversely affected any other readily soluble manures to the same extent, yet the Nitrate of soda plots show a very fair increase for 1922 and, moreover, their yield is above that of any of the three series receiving relatively insoluble manures.

A brief consideration of the weather and soil conditions at the time of, and for some months immediately after, the application of the manures is of interest, more particularly in relation to the readily soluble ones, and the following table shows the total rainfall and its approximate distribution for every year of the experiment and also the average soil moistures for the months of April, May and June from 1921 onwards.

TABLE II.

		1920.	1921.	1922.	1923.
April	Rainfall in inches ...	9·08	14·03	7·79	10·84
	Days on which rain fell ...	17	22	8	22
	Average soil moisture ...	...	19·6%	13·9%	17·81%
May	Rainfall in inches ...	6·73	9·28	6·13	11·97
	Days on which rain fell ...	15	17	15	20
	Average soil moisture ...	...	17·35%	16·5%	18·3%
June	Rainfall in inches ...	9·89	7·71	11·67	20·29
	Days on which rain fell ...	20	25	28	20
	Average soil moisture ...	...	18·22%	17·5%	18·75%

° Soil moistures during April 1920.

1st—10th ... 15·88%
11th—25th ... 11·69%, & fell to 10·17% (No rain).
26th—30th ... rose from 15·76% on 26th to 21% on 30th (6·01" rain fell).

° NOTE:—Soil moistures were not regularly recorded until 1921.

In considering this table and its bearing on the yields shown in Table No. 1 it must be noted that whereas in 1920 the manures were not applied until the end of May, and the bulk of the Green Manure not until mid July, in 1922 they were applied in the middle of April, and in 1923 during March, except for the Oilcake and a small balance of the Sinews which went on early in April.

As was noted by Harler (2), in a previous issue of this Journal, the early season of 1922 was poor, and compared very unfavourably with that of 1920, although, as may be seen from the above table, the total rainfall between April 1st and June 30th was almost identical in the two years.

Reference to the distribution of this 25½ inches of rain, however, reveals the probable cause of difference in the seasons ; for whereas 15·18 inches of it fell on 23 days in April and May of 1920, in 1922 only 13·92 inches fell on 23 days before June, and of this nearly half fell on six consecutive days at the end of April immediately following a fortnight's drought, so that much of its value must have been lost on such a light soil as that of Borbhetta where percolation is rapid.

The 1923 season did not start well, in spite of the heavier rainfall from April to June and the fact that it was fairly evenly distributed over the three months.

Possibly the soil was too wet during a large part of this period for the manures applied to produce their optimum effect, or more likely still the air temperature, which was kept unusually low for this time of year by the continual falls of rain, may have exerted a retarding influence on growth.

Attention has been called to the latter factor, in the Meteorological Report of this Department for 1923 by Harler (3), who says—"March was a dry month and it was during this period of drought and rapidly-rising temperatures that the poor start of the season was definitely decided . . . . Both April and May were wet, cool months which retarded the start of the season." Lehenbaure's (4) statement, which is quoted by Harler (2), that "between the vital temperature" (*i.e.*, 42°F below which plant

growth ceases), "and the optimum, the rate of growth is doubled for every rise in temperature of 18°F is of particular interest in this connection, as the optimum temperature at this time of year is high, owing to the comparatively short duration of the exposure of the plant to sunlight.

Whatever the cause however, the season was a late one and finished exceptionally well thereby favouring the slower acting manures, all of which, even Sinews, gave an average of over a maund of leaf per acre for the last two or three pluckings in November against only half that quantity, or less, on the Nitrate of soda and Sulphate of ammonia plots.

As might be expected, the quick-acting chemicals give a relatively heavy yield at the beginning of the season and a correspondingly early close. The slower acting organic manures are steadier yielders and tend to give more leaf in the latter half of the season, this being particularly the case with Green Manure. This is illustrated by the graphs facing this page.

Finally, as regards the economic value of the five types of manure under trial, the following Table gives the cost of each, at present market prices (April 1924), and their relative values as crop producers, based on those costs, and expressed as the cost per acre of producing one maund of tea increase on an average annual yield of approximately 8½ maunds, from an unmanured light sandy soil, such as that of Borbhetta.

Manure.	Nitrogen content.	Price per ton * (at Borbhetta).	Cost of manures per acre per annum.	Cost per acre of producing 1 md. Increase over unmanured crop.	
		Rs.	Rs.	Rs.	As.
Green Manure	1%	...†	3/6	3	3
Nitrate of Soda	15%	260	22/15	11	3
Oilcake	5%	77	20/10	20	10
Sulphate of Ammonia ...	20%	215	14/7	22	3
Sinews	10%	145	19/7	No increased crop.	

* Rs 15/- per ton has been added to Calcutta prices for freight and 2 annas per maund for carting from Jorhat in case of Oilcake.

† Cost of seed (if any) and labour for cutting and applying only about 6 haziras per acre. Cost will, of course, vary very greatly according to distance of Green Manure from tea.

It must be emphasised that the costs given in the right hand column of the above Table are not to be regarded as universally applicable, for they are bound to vary with local conditions, particularly as regards soil and climate.

These figures are therefore only given as affording a direct comparison between the costs of the crop in cases actually produced by the various manures in the course of these experiments. At the same time it is believed that, given similar conditions, they would form a very fair guide for making a choice from the types under trial in order of economy.

Extension series (1923).

With a view to increasing the scope and utility of these trials, they have been extended from the beginning of the 1923 season by the addition of twelve more plots, each approximately 3/40th of an acre in extent, arranged in three groups of four plots each, so as to test the relative values of three more types of Nitrogenous Manures against a check series.

The bushes on these plots are also of the Matelli variety and were planted in 1916, having come from the same nursery as those on the original eighteen plots of the experiment, but, after being collar pruned as they became ready during 1919, they have been treated in a somewhat different and more orthodox manner.

Thus, while the original plots have been top pruned annually from 1919 onwards, these plots were left unpruned in 1919-20 and were only heavily skiffed in the cold weather of 1920-21 and then given six inches new growth before being plucked to allow the originally weak bushes to become stronger. In 1921 they were cut down to eight inches from the ground, and after being again left completely unpruned in 1922, they have now been cut down to four inches of new wood in February, 1924.

Manuring up to and including 1922 has been the same on all the plots, as follows :—

1916. Bad patches cattle manured. Boga medeloa broadcasted in May and hoed in August, prior to planting of tea in November.

1917. Nil.

1918. 10 mds. per acre Lime applied in December.

1919. 1 cwt. per acre Bone dust and Superphosphate mixed in proportion of 7 to 2, applied early in June, followed by Cowpeas in every line at 15 seers per acre. The Green crop, however, failed and was therefore re-sown in August, when a fair but patchy crop was obtained, the total of organic matter hoed in from both crops being not more than 2 tons per acre.

1920. Nil.

1921. Nil.

1922. Bone dust, Nitrate of potash and Nitrolim at 120, 60 and 100 lbs. per acre, respectively, applied in April.

After having been plucked for $2\frac{1}{2}$ seasons for Initial Fertility records, these plots were taken into experiment last year on the same lines as the six series already under trial and were accordingly all manured on the 7th of May with Bone dust equivalent to 35·6 lbs. phosphoric acid per acre, immediately following which one plot in each group was dressed with Milled Fish Guano, one with Sterilised Animal Meal (ordinary) and one with Nitrolim at the rate of 30 lbs. Nitrogen per acre, the remaining three plots being left to act as checks and not further manured.

The following table shows the initial fertility yields of the four series prior to the application of Experimental manures, and the crops produced by those manures in the first year of the Experiment :—

TABLE.

	Initial Fertility Yields.				30 lbs. Nitrogen per acre applied 1923 as—	Pucca tea per acre. Corrected yields 1923.
	1920.	1921.	1922.	Total 3 years.		
Plots 65, 69, 73 ...	·50	6·10	3·46	10·06	Fish Guano	14·32
„ 66, 70, 74 ...	·56	5·78	3·44	9·78	Animal Meal	13·75
„ 67, 71, 75 ...	·65	6·25	3·85	10·75	Nitrolim	13·51
„ 68, 72, 76 ...	·61	6·34	3·82	10·77	Check (No manure.)	12·51

It is of course too early for these results to be regarded as having any appreciable significance, but it will be observed that some alteration in the order of the yields has already taken place.

An important factor operating against the success of Nitrolim was the fact that, owing to the small quantity required for this experiment having been ordered separately, it was sent up from Calcutta in bags instead of in the usual sealed drum, and on arrival at Tocklai had deteriorated considerably from contact with atmospheric moisture.

References.

(1) Cooper—Indian Tea Association, Scientific Department, Quarterly Journal, 1922, Part I.

(2) Harler—Indian Tea Association, Scientific Department, Quarterly Journal, 1922, Part II.

(3) Harler—Indian Tea Association, Scientific Department, Quarterly Journal, 1924, Part I.

(4) Lehenbaure—Int. Rev. Sci. Prac. Agr., Year XII, No. 8, p. 934, August 1921.

THE MECHANICAL ANALYSIS OF SOILS

BY

C. R. HARLER, B.SC., F.I.C.

SEDIMENTATION.

Practically all the tea soils of North East India are sedimentary soils and the only ones which have been formed *in situ*, from the rocks beneath them, are those of the Darjeeling district and the red sandy *teelas* of the Surma Valley. As rocks are denuded the particles are carried away by rivers and deposited, anything from a few miles to well over a thousand miles away. The distance through which a particle is transported depends on its size and also on the speed of the water flow. The table below shows the speed necessary to move particles of different sizes.

RATE OF WATER FLOW.							SIZE OF PARTICLES MOVED.
3	ins.	per	sec.	or	0·170	miles per hour	... Clay
6	,,	,,	,,		0·340	,, ,, ,,	... Fine sand
8	,,	,,	,,		0·455	,, ,, ,,	... Sand as coarse as linseed
12	,,	,,	,,		0·682	,, ,, ,,	... Fine gravel
24	,,	,,	,,		1·364	,, ,, ,,	... Pebbles 1″ in diam.
36	,,	,,	,,		2·045	,, ,, ,,	... Small stones

By following the course of any of the rivers in the tea districts a fairly regular gradation of the soil is noticed from the gravel and stones near the hills to the fine sands and silts met lower down the course. With the coarser particles a certain amount of clay is also deposited but a real clay is seldom laid down by the rivers of Assam owing to their swift currents.

In some cases it is difficult to explain the formation of the soil. Thus on the Upper Mangaldai bed where the slope of the land is considerably more than six inches to the mile, which is the maximum fall for silt deposit, the soil contains many more fine particles than would be expected. This is probably due to the fact that the Khagra jungle which grows in this district has impeded the free flow of surface wash and thereby allowed time for the silt and clay particles to settle.

In many soil sections there occur rapid alternations of coarse and fine grained soils denoting that the current depositing them was capable of constant fluctuations in velocity. It is sometimes noticed that coarse sand and clay occur in distinct bands, especially in areas subject to the vagaries of flooding. One common explanation is that water which may for some time have been depositing sand has its flow suddenly stopped, perhaps because the river is backing up and this gives the fine particles time to settle and deposit the coarser ones higher up the stream.

It will be seen at once that a flow of water over a soil may be fast enough to remove the finer particles and deposit the coarser ones. It is only when water quietly backs up over land and deposits a fine silt that it becomes a creative and not a destructive force so far as laying down a fertile soil is concerned. It sometimes happens with tea however that an alkaline deposit of silt kills out the bush although for other crops the soil may be enriched.

In order to separate the particles of a soil into groups according to their size, a process based on sedimentation is used. After the stones, gravel and coarse sand are removed by sifting, the remainder of the soil is suspended in water. By allowing the coarser particles to settle, the finer ones remaining in suspension are separated.

It is also possible to imitate the action of a river in the laboratory by passing water flowing at a certain rate over a soil, thus separating the particles, which will be moved through distances according to their size.

It has been found convenient to divide soil particles into six groups as follows :—

	Soil Fraction.	Diameter of particles in millimetres (mm.)
Separating by sifting	Gravel and Stones	above 1 mm.
	Coarse sand	1 to 0·2 mm.
	Fine sand	0·2 to 0·04 mm.
	Silt	0·04 to 0·01 mm.
	Fine silt	0·01 to 0·002 mm.
	Clay	below 0·002 mm.

These dimensions are quite arbitrary ones but experience has shown them to be convenient. An appreciation of the various sizes is obtained when it is mentioned that one millimetre equals 1/25th of an inch.

The Mechanical Analysis of a Soil.

Sampling.

To allow comparison of one soil with another the surface soil is arbitrarily defined to consist of the top nine inches, and a fair average sample can only be taken by means of an auger from several places located over the area under study. The total sample is well mixed and dried and then sieved to remove the gravel and stones. Most tea soils in Assam are devoid of any particles larger than coarse sand. When stones do occur they have been deposited from the hills close by and not by the Brahmaputra River.

Hygroscopic moisture.

The air dried soil still retains a small quantity of water which depends on the moisture in the atmosphere. If the atmosphere were perfectly dry (an unknown phenomenon) then the soil sample would also become dry. Actually each particle is surrounded by a film of moisture the thickness of which depends on the atmospheric humidity.

The finer the soil particles the greater will be the hygroscopic moisture of a soil, for the relative surface of a soil increases as the particles become smaller. Although the hygroscopic moisture is some measure of the fineness of a soil little attention is paid to this figure.

Soluble in dilute acid.

The first stage in the sedimentation process of mechanical analysis consists in rendering the soil into a fit state for suspension in water. Many particles are cemented together by lime and other substances so that there is a chance of groups of particles falling from suspension and being thereby classed as belonging to a coarser grade. In order to obviate this error a weighed amount of the soil is shaken for an hour with a weak solution of hydrochloric acid after which it is filtered. The action of the acid is to dissolve out the cementing

material and to break up aggregates. After the soil has been filtered it is dried and weighed and the loss in weight represents the amount soluble in dilute acid.

Coarse sand.

We next proceed to the actual separation of the particles into the various groups. Ten grammes of soil are used for analysis. The coarse sand is separated by sifting through a 90-mesh sieve. The sample is washed on to this sieve and the smaller particles are pushed through the meshes by means of a brush and copious washings of water.

The coarse sand fraction does not enter much into the chemical reactions of a soil, but it may be regarded as a kind of frame work on which the soil is built. The coarse sand naturally keeps the soil open and makes drainage easy, but, on the other hand, too much of this fraction makes the movement of moisture so easy that the soil may be liable to dry out in a drought.

The Clay Fraction.

When the coarse sand has been separated the remainder of the soil is put into a glass cylinder and ammoniated water is poured in till it reaches a height of 11 cms. The soil is well stirred and then allowed to settle for 24 hours. During this period all the fractions that are coarser than clay settle to the bottom leaving this fraction in suspension. The liquid is carefully poured off and the clay fraction with it. Now some of the clay particles which at the end of the stirring process happened to be in the lower part of the cylinder will have been carried down with the larger particles, so another lot of ammoniated water is poured on to the soil which is again stirred, allowed to settle for 24 hours and decanted off. This process is repeated till at the end of 24 hours the liquid is quite clear. The decanted liquids are then evaporated to dryness and the clay is weighed.

It is now necessary to consider what actually constitutes clay. A clay particle we know is one having a diameter of less than 0·002 mm. A particle so small in size takes on peculiar properties by virtue of its large surface compared with its mass. Such a particle will remain suspended in water for a very long period, perhaps for years, before it settles. These

particles belong to the class of bodies known as *colloids* and one important property is their power of aggregation. In the soil, clay particles collect in groups. When the individual particles are not aggregated they fill the pores of the soil which then tends to become a solid mass. This breaking down or deflocculation of clay aggregates brings about a loss in tilth in the soil.

When clay is suspended in water the particles still continue to move about in groups and as such tend to settle more quickly than the single clay particles would do. Each aggregate carries a positive charge of electricity, which in some way keeps the group together, but when ammoniated water is added to a soil solution, the charge is neutralised and each clay particle is then suspended separately in the water.

The clay fraction is an essential part of the soil. Without these minute particles—either mineral or organic—we cannot picture a true soil. Undoubtedly the clay fraction supplies most of the plant food and, in addition, steadies the movement of the soil moisture.

Most clays are hard to work, but a soil even if it contains over 20% clay will be permeable and easily cultivated if the organic matter present is sufficiently high, say 12%.

It is further necessary to distinguish between particles which act in a manner similar to fine silt and those which take on sticky properties. It is common to have two soils showing a similar mechanical analysis, yet one of them may be sticky and hard to work and the other may be light and friable. This difference probably arises from the fact that the clay fraction in the sticky sample consists of particles well under the size limit, whereas in the light sample the clay particles are only just smaller than fine silt.

Fine silt.

After the clay has all been removed, the remaining part of the soil is stirred with water and allowed to settle for twelve minutes. During this period all particles larger than fine silt settle and when the liquid is decanted the suspended silt is removed. As with the clay fraction some of the silt particles will be carried down with the coarser particles and so the settling process must be continued till, at the end of twelve minutes, no particles remain in suspension.

Silt and Fine sand.

After the fine silt has been removed only the silt and fine sand fractions remain. These two fractions are stirred with water in the cylinder and allowed to settle for 100 seconds. This process is repeated till all the silt has been removed and only fine sand remains.

The properties of silt and fine sand are similar and vary only in degree. If fine sand is present in great proportion it is liable to make a soil hard and "steely" in the dry season or after a rainy spell followed by sun.

For this reason fine sands make bad nurseries although, so far as the tea bush in concerned, a top crust does not matter much. Silt and fine silt make a soil subject to tight packing, and anything tending to loosen the packing of silty soils, *e.g.*, the addition of organic matter, is to be recommended.

The loss on ignition.

The loss on ignition is an important factor in the mechanical analysis of a soil. This factor represents, in the main, the organic matter in the soil, although in part it represents the water of crystallisation and hydration of the various minerals. In a full mechanical analysis each fraction, as it is separated, is weighed before and after ignition. Thus we are given an idea of the quantity of organic matter in each fraction.

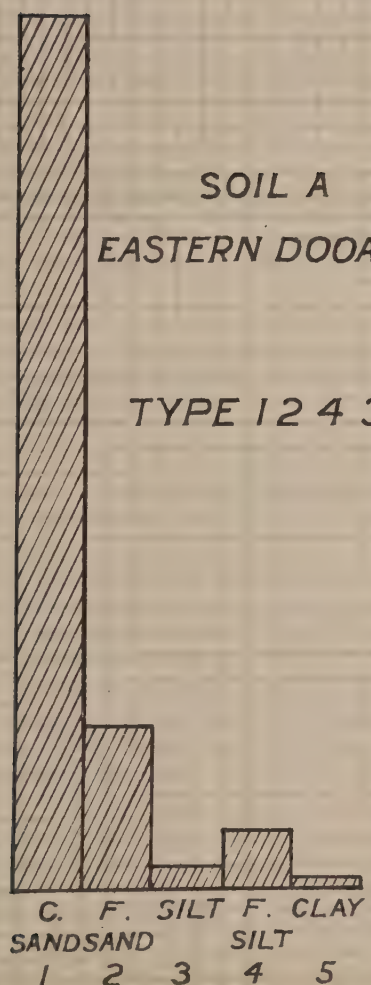
The Classification of Soils.

It is possible to classify a soil by its feel and look. By this method a soil would be called a clay, a silt, or a sand. A soil containing clay and sand as its chief components is a loam. Soils containing much clay and lime are known as marls, but such soils are practically never met in the tea districts of North East India.

It will be seen that there is need for a definite and scientific classification of soils. Many systems have been employed, each one being more or less suited to a certain area. Soils may be classed from a geological point of view, but this classification only leads to a general division and gives rise to such extensive types as glacial, residual and alluvial formations.

Another factor which may be used as a basis of classification is the type of climate. Thus an arid climate gives rise to a certain kind of soil usually rich in sand and silt and containing a high

GRAPHIC REPRESENTATIONS OF MECHANICAL ANALYSES.



SOIL A

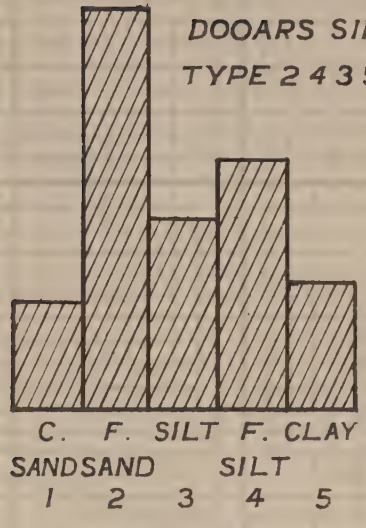
EASTERN DOOARS

TYPE 12435

SOIL B

DOOARS SILT

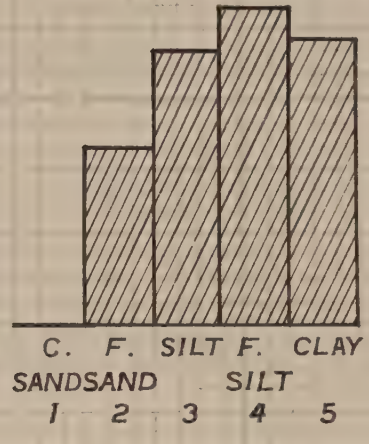
TYPE 24351



SOIL C

ASSAM YELLOW CLAY

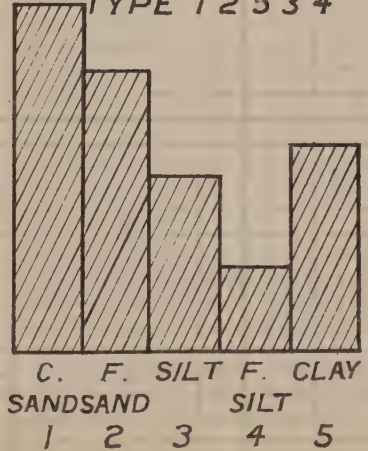
TYPE 45321



SOIL D

SOUTH SYLHET TEELA

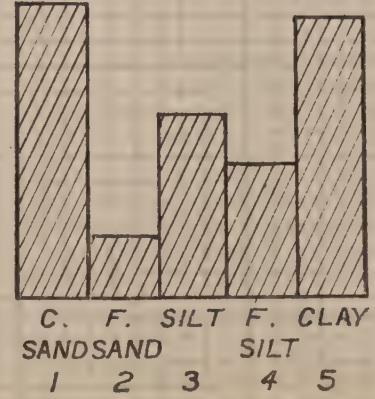
TYPE 12534



SOIL E

DARJEELING

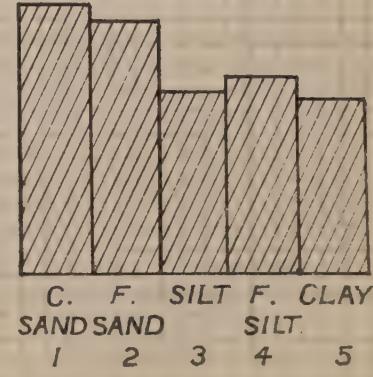
TYPE 15342



SOIL F

TEZPUR RED BANK

TYPE 12435



percentage of soluble salts, lime and magnesia. A humid soil, on the contrary, has been submitted to much leaching, which makes it poor in soluble salts, and to a great deal of weathering which produces finer soil constituents. Humid soils have usually lost most of their lime and are often highly coloured, owing to large quantities of iron. The soils of Assam come into this class.

Still another way of dividing soils is according to the type of vegetation they carry. Thus a semi-arid soil may be classed as a prairie soil and a humid soil as a timber soil.

The classification which has been found to be most satisfactory is one based on the texture of the soil, on the size of the particles and on the proportion of particles of each size in the soil.

The method used at Tocklai is at first confusing, although it is simple and direct. Each soil fraction is denoted by a number as is shown below :—

Coarse sand	denoted	by	No. 1
Fine sand	,,	,,	No. 2
Silt	,,	,,	No. 3
Fine silt	,,	,,	No. 4
Clay	,,	,,	No. 5

Then the fraction which occurs in the greatest proportion is mentioned first, followed by the other fractions in order of magnitude. The method will be seen at a glance from the sketches opposite which illustrate the soils shown in the table.

	Soil A.	Soil B.	Soil C.	Soil D.	Soil E.	Soil F.
	Eastern Dooars Coarse sand.	Dooars silt.	Assam yellow clay.	South Sylhet teela.	Darjeeling.	Tezpur Red Bank
	%	%	%	%	%	%
Coarse sand	76	9	nil.	30	25	23
Fine sand	14	35	16	24	5	22
Silt	2	17	24	15	16	16
Fine silt	5	22	28	7	11	17
Clay	1	11	25	18	24	15
Soil type—	12435	24351	45321	12534	15432	12435

Soil A is a sand from the Eastern Dooars, the lightest known in the tea districts, of the type 1, 2, 4, 3, 5. It was laid down by fast running water which carried off practically all the finer particles. The predominance of the coarse sand is such that the influence of the other fractions is quite over-shadowed.

Soil B, of the 2, 4, 3, 5, 1 type is a typical silt from the Daina-Toorsa district in the Dooars. It was laid down from water flowing at a medium pace which has dropped most of the coarse sand. The coarse sand then, the 1-fraction, takes the last place in the chain and the finer fractions increase in importance. Such a soil as this one containing much fine sand and silt is liable to tight packing, lacking as it does the opening influence which would follow from a good percentage of coarse sand.

Soil C of the type 4, 5, 3, 2, 1 is a yellow, sticky clay from Assam, difficult to work and almost impervious. This soil was laid down from water which was almost stagnant. A notable feature is the entire absence of coarse sand which is naturally never deposited in large quantities with clay. The yellow clays are usually much stickier than the red ones which are often much older and have had the sticky particles removed by ages of washing.

E and F are given as examples of soils formed *in situ*. Soil E is taken from a South Sylhet *teela* and is of the type 1, 2, 5, 3, 4 which is characteristic of this area. Soil F is from Darjeeling and is of the type 1, 5, 3, 4, 2. The outstanding feature is that both clay and sand are major constituents. Now since coarse sand and clay cannot be deposited as major fractions from running water it follows that the clay has been formed by weathering.

An examination of the subsoil of the Sylhet *teelas* yields interesting information. The core of the hill is made of sandstone which has not weathered so much as the top soil and is hence much poorer in clay. The subsoil immediately below the soil, on the other hand, is usually much heavier than the top soil, for with a soil of the 1-5 type there are not many fine particles to stop the washing down of the clay during each rain. During the dry

season this clay band, which has been washed down, hardens and after many years the ironstone pan common in South Sylhet makes its appearance.

Soil F is of the type 1, 2, 4, 3, 5 from the Tezpur Red Bank. Although it is denoted by the same type chain as Soil A it is essentially different in texture. These two cases illustrate the weakness of this method of classification. The Tezpur soil although not so old as the Sylhet example has still had time to weather and to thereby increase the clay percentage to 15% whereas a similar soil laid down recently would only contain 4 to 8% of this fraction.

The Interpretation of a Mechanical Analysis.

The interpretation of a soil analysis can only be made in the light of practical experience. The most we can say is that a soil giving a certain analysis will respond to the same treatment as a soil in the same area giving a similar analysis. For instance, the same treatment will probably get the same response from soils on the Dooars Red Bank when the analyses are similar, but it would be unsafe to argue that similar soils in Assam would act in the same manner.

The application of manures can only be scientifically made after the mechanical condition of the soil is known. Two hypothetical soils, both rich in plant food, are shown below :—

	Soil A.	Soil B.
Coarse sand	45	5
Fine sand	25	10
Silt	15	15
Fine silt	10	30
Clay	5	35
Loss on ignition... ...	4%	9%
Nitrogen	0·13	0·22
Organic matter (Grandeau) ...	1·4	3·0
Available potash ...	0·010	0·018
„ phosphate ...	0·029	0·046

Soil A is a light sand which will allow the plant roots to explore a great area with ease, whilst soil B is a clay which

restricts free root development. On this account both soils are accounted rich, although Soil B contains about twice the amount of plant food as soil A. In addition, it should be added, the plant food from a sand is generally more available than that from a clay. For tea, soil A is preferable to soil B.

Having decided by the help of the mechanical and chemical analysis that a soil needs a certain manure, the form in which the manure may be best added can then be decided. For example, nitrogen may be added as cattle manure, oil cake, nitrolim, sulphate of ammonia, nitrate of soda, nitrate of potash and in the form of many other manures of a mixed nature. Now experience has shown that certain manures act better than others on certain types of soil and in suggesting a manuring scheme the mechanical analysis of a soil is essential.

Thus if we decide that a soil of physical texture resembling B requires nitrogen, it would be inadvisable to give it as oilcake, for the rate of decomposition by which the nitrogen in this manure becomes available is so slow in clay soils that its application is not economically sound. With such a heavy soil the nitrogen would be best added as sulphate of ammonia. Whilst oilcake does well on a light sand like that shown by soil A, nitrolim does not do well, or at any rate gets but a poor response. At Borbhetta where the soil is of the type 2, 1, 3, 4, 5 nitrolim gave a crop increase of 4% whilst an equivalent quantity of nitrogen added as fish guano gave an increase of 14%. It is generally sounder to add manures in an organic form to a sandy soil.

In practice, the mechanical is of more use than the chemical analysis to the chemist, for experience has shown that so far as the tea crop is concerned, practically every soil responds to nitrogen, whatever the chemical analysis may show. The important point is to know in which form to add the nitrogen, and this can only be deduced from the mechanical analysis.

The present article makes no pretentions to completeness in discussing the mechanical analysis, of a soil, but before leaving the subject some indication of the theoretical meaning of the subject

should be given. The type of soil varies according to its mode of formation. Thus in the upper reaches of the Brahmaputra River a normal soil would be of the type 1, 2, 3, 4, 5 with the coarse sand greatly in excess, and the clay present in small quantities. As we proceed down the river and the slope of the land decreases and the large particles are left behind the predominance of coarse sand will be less marked until we eventually get a soil of the type 2, 1, 3, 4, 5 or even 2, 3, 1, 4, 5 Still further we should expect the fine sand to give place to silt as the greatest fraction and soils of the type 3, 2, 4, 1, 5 and 3, 4, 2, 1, 5 would be met, each steadily getting heavier. The soils with silt as the chief constituent are however rare in Assam.

When a soil is formed *in situ* by weathering, then there is a tendency for the clay to increase. The two types—

1, 2, 3, *4*, *5*
1, 2, 3, *5*, *4*

represent a sedimentary soil such as is met near the Brahmaputra and a soil from a South Sylhet *teela* which has gradually formed from the sandstone rock which constitutes the core of the *teela*. Similar types are 1, 2, 5, 3, 4 and 1, 5, 2, 4, 3 where the clay is seen to be gradually increasing in importance. It is contrary to experience or expectation to have coarse sand and clay deposited together in anything approaching equal quantities by running water. If these two fractions do tend to become equal it is due to weathering.

In the Brahmaputra Valley the soils vary enormously in age. There are the River *churs* which were deposited but a year or so ago and may be swept away by the next floods. There are again such *churs* which have become consolidated by vegetation so that they are able to resist further attacks by the River. The next stage is when the white and grey soil tends to become reddish with age. Such soils are found in the Jorhat district. There are still older soils put down in a different era in the geological history of the valley. The soils referred to are the red soils which crop up from the newer alluvium. In these soils the clay fraction has considerably increased since the soil was first deposited.

Top soils are subject not only to weathering but to surface washing so that any clay gained by the one process may be removed by the other. The deeper subsoil does not submit to washing to anything like the same extent and here it may be possible by a careful study of the amount of the clay fraction, its position in the type chain and its relationship to the other fractions, to get a rough idea of the relative ages of our soils.

ROTATION OF MANURING

BY

H. R. Cooper, B.Sc., F.C.S.

From records of manuring it is observed that the effect increases as the manuring is carrried on. While a single application of manure may give a small and possibly almost unnoticeable increase, yet if the manuring is carried on for several years, the manured area improves relatively annually till it gives a very paying increase, if of course the manures used have been suitable.

Thus on normal good soil a dressing of 7 mds. oilcake generally produces an improvement of about 5% only, a difference so small that it requires the most accurate experiment on a large number of plots to make it clear that there has been any improvement at all. If, however, the treatment is continued annually, then by the end of four years the manured plot will show an improvement of something like 20% relative to a check plot, which improvement is distinctly noticeable. Nor will improvement end there ; but if the treatment is carried on, an improvement of something like 50% may be expected in little more than 10 years, after which it is probable that improvement would be slower till it reaches a point when continued application of manure only maintains the high yield.

The actual increase per annum would of course vary according to the soil, and to the efficiency of the manure used. The point which it is desired to make clear is that while sporadic addition of manures may not and frequently does not pay, steady and continuous manuring will do so.

The amount of manure used may be so small that there is little, if any, permanent increase in the fertility of the soil ; but the increased yield is produced from bigger bushes with a larger number of flushing shoots. That the majority of tea soils are

capable of maintaining bigger average bushes, is shown by the fact that a few naturally strongly growing bushes can always be noticed as enormously above the average in size and yielding capacity.

The small quantities of manure commonly used in tea culture, appear to act by producing a larger number of shoots rather than by forcing more rapid growth.

This conclusion is supported by the fact that residual effects are produced even when water soluble nitrate of soda is used, although it is known that the whole of this manure is certainly used up or washed out before the end of a single season. In such a case the residual effect cannot be due to any manure remaining in the soil, but any gain in following seasons can only be ascribed to the fact that a better bush has been formed by the previous manuring.

The main requirement for tea is nitrogen, and we should make a point of getting it in early (not later than April) in order that the bush may make full use of it in the spring months during which wood growth is rapid.

It should be our object to provide a little increased available nitrogen every spring, and that no doubt is the main requirement for tea. At the same time, however, we must see that sufficient phosphoric acid, potash and lime are also provided, unless these are naturally present in the soil in ample quantity.

We have also to keep in mind the undoubted fact, that of all factors affecting the fertility of the soil, its organic matter content is the most important, that the organic matter continuously disappears under cultivation, and that for this reason above all the soil deteriorates. Nor can deterioration from this cause be altogether corrected by the addition of concentrated fertilizers. The organic matter stabilizes a soil, makes the tea it carries more resistant to bad weather conditions (*e.g.*, drought) and to many "weakness diseases" (*e.g.*, red rust, and die-back diseases). Thus at Rothamstead, plots receiving stable manure give a fairly steady yield in good seasons and in bad, while plots receiving artificials only (although always better than plots which get nothing) may give

very large increases in favourable seasons, but small increases only in bad seasons. Further, the plots receiving artificials only over very long periods show a small but steady decrease in yield. This is much smaller than the decrease shown by unmanured plots, but the plots receiving organic matter do not show this decrease. Tea soils have to carry the same crop for an unlimited time. We must look upon the upkeep of the organic matter, as the point of chief importance in the maintenance of the soil's fertility.

For this purpose, of the materials we have at hand cattle manure is of chief importance. It is already used fairly widely, but probably more could be used, if its value were better appreciated. It ought not to be too difficult to find a ton per acre of tea, say 4,000 cart-loads annually for a thousand-acre garden, if the manure produced by the cattle in the garden itself were properly conserved. Application is expensive but there are times, particularly in droughty springs, when there is little urgent demand on labour, and cattle manure is best applied early and so can go on whenever labour is available.

The subject of storage of cattle manure was dealt with in Quarterly Journal, 1918, Part II, p. 55.

In some situations there may be green jungle or a specially grown crop conveniently near which can be cut and carried on to the tea land, but such cases are rare. To back up such cattle manure as is available we have in the main to rely on green manures grown on the spot and hoed in, either rapidly growing ground-crops like cowpeas and dhaincha or semi-permanent high crops like boga medeloa, or arhar. Before deciding on our systematic manuring we have first to decide how much green cropping can be done with the available labour.

The ground crop is usually the more difficult to deal with, because it requires labour all at one season. In practice it has to be hoed in from a time about six weeks after the first good rain up to the middle of July at latest, after which the presence of the crop seriously hinders plucking. The question to be answered by each planter is simply this,—How many acres of green crop can I hoe in during May and June (say nine weeks) without allowing

the remainder of the garden to go into jungle? The answer usually is about one-fifth of the garden. Many do much more and a few find difficulty with so much. Whatever the fraction is, it decides the number of years over which our system of manuring is to be spread; for example, if $\frac{1}{5}$ of the garden can be treated annually, then the whole garden can be completed in five years.

Every effort, however, should be made to get in more organic matter than this. It can, for example, be supplemented by the use of semi-permanent crops, like boga medeloa. These require cutting occasionally, both to prevent over-wide spread becoming a nuisance, and to get the organic matter into the soil; and eventually the remaining green parts of the plant should be trenched or deep-hoed in, which also requires labour. This is not strictly a manuring question, but one of cultivation. The two, however, must often be considered together. It is sound to vary the depth of cultivation; occasional trenching is certainly very generally useful, and when we trench we must have something to put in the trenches.

In systematic manuring we should certainly seek to add our manures so that they assist each other as far as possible, and so that each is applied just when it is likely to prove most valuable.

Lime appears seldom to be required for the growth of tea, or, at any rate, to be required less than most other manures, so that of a limited expenditure a small proportion only will normally be spent on lime. With most of the crops used for green manure, however, the good effect of lime is generally great. If then, lime is to be included in the rotation it should be added so that the green crop will be helped by it. The effect of lime on a green crop appears to be greatest in the year following that in which the lime was applied. In the rotation therefore the green crop should be sown in the year following that in which lime was applied.

Leguminous crops have the power of taking nitrogen from the air and using it for their own growth. If, however, there is ample nitrogen in the soil, the legume uses that and commonly does not take nitrogen from the air. *We should, therefore not use any form of nitrogenous manure for the green crop.*

Phosphatic manures are not washed out of the soil but remain there until used. Phosphatic manures have been shown on most soils to exercise a very great good effect on the growth of leguminous crops. Early root growth, and the development of the nodules, which are the homes of the nitrogen-fixing bacteria, are both stimulated. Phosphates produce early maturity, a great point in getting a big crop in a short time; and the shorter the time the ground is occupied by the green crop the better, for the growth of the tea is adversely affected during that time. The tea also suffers for a time after the green crop is hoed in, and the presence of phosphates shortens that time. Hence it will be sound to use a large proportion of the phosphate which we propose to use in our rotation, together with the green crop.

After this green crop has gone in, our soil will be in improved condition to give good results from added nitrogenous manure, the most expensive item of the programme.

When potash is required there is some evidence to show that both it and the nitrogen will do better put on together than if separately applied.

We have now included at least a little of all things which a soil can require, *i.e.* lime, organic matter, nitrogen, phosphate and potash, and have settled that they should go on in the following order :—

1st Year. Lime.

2nd Year. Phosphate and green crop.

3rd Year. Nitrogen and potash.

If we are to use a five-year system, the above certainly does not provide enough.

If limitation of expense is the main object, we can fill in the last two years as below :—

4th Year. Boga medeloa sown in hedges, and lopped up the sides as necessary.

5th Year. Occasional cutting of boga medeloa continued. Remainder trenched or deep-hoed in at end of season.

The above may be conveniently regarded as a minimum, and every effort made to maintain so much even in bad seasons (except that the lime could be dropped with little loss on most soils), while in seasons of good prices it is certain to pay to use much more. An example of a good system, as economical as possible, is given below, the manures chosen being such as would suit average soils. One cannot at this point go into further detail, the object being merely to illustrate the principles of the rotation and not those governing the selection of particular manures.

Treatment (*a*)—Slaked lime 10 mds.
or
Crushed limestone 12 mds. } broadcasted.
and
5 tons cattle manure—broadcasted.

Treatment (*b*)—40 lbs. Phosphoric Acid per acre—

e. g. 200 lbs. Belgian Flour Phosphate scattered along seed beds for green crop, *e. g.* 15 seers cow-peas per acre.

Treatment (*c*)—Mixture to provide 30 lbs. nitrogen and 20 lbs. potash per acre—

e. g. 150 lbs. sulphate of ammonia.
40 „ muriate of potash. } Forked in around bushes.

Treatment (*d*)—40 lbs. Phosphoric Acid per acre—

e. g. 200 lbs. Belgian Flour Phosphate broadcasted.

Boga medeloa to be sown in hedges, and lopped as required.

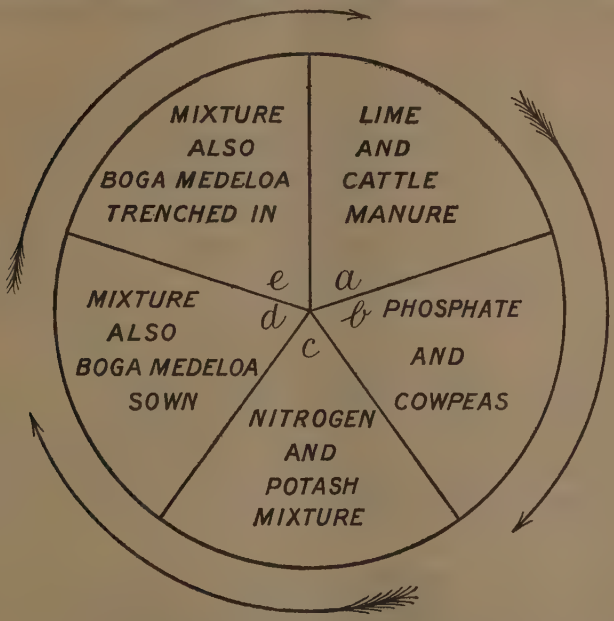
Mixture as in treatment (*c*) forked in around bushes.

Treatment (*e*)—Mixture as in treatment (*c*) forked in around bushes.

Boga medeloa kept up and lopped occasionally till trenched or deep hoed in at end of season.

We want to apply this system to the whole garden; but it is not necessary (or possible) to *start* the whole garden with the same treatment. The rotation can be started anywhere, but whatever

treatment is given as a start it must be followed by all the others in the right order, according to the following diagram :—



SPECIMEN ROTATION OF MANURING.

The block which starts the rotation at treatment (*e*) for the first time, will have no boga medeloa ready sown. This difficulty could be met at the beginning of the season by sowing arhar which would be ready at the end of the same season, or by cutting and carrying green jungle if any were conveniently near.

To apply the rotation, the garden will be divided into five blocks of roughly equal area which will be treated as below :—

	Block 1.	Block 2.	Block 3.	Block 4.	Block 5.
1st Year	treatment A	treatment B	treatment C	treatment D	treatment E
2nd Year	B	C	D	E	A
3rd Year	C	D	E	A	B
4th Year	D	E	A	B	C
5th Year	E	A	B	C	D

Using the manures suggested which are the cheapest of their respective kinds on the present market, the approximate cost (allowing 8 annas per maund for freight from Calcutta) would be—

	Rs.	As.
10 mds. slaked lime about ...	20	0
5 tons cattle manure, say ...	20	0
400 lbs. mineral phosphate ...	13	5
450 „ sulphate of ammonia ...	45	0
120 „ muriate of potash ...	8	8
15 seers cowpeas	2	8
	Rs. 109	5

or about Rs. 22 per acre per annum, which does not include application.

Where sulphate of ammonia is considered unsuitable nitrate of soda could be substituted at increased cost of about Rs. 5 per annum per acre.

If an organic manure is preferred, 8 mds. oilcake could be substituted for each application of 150 lbs. sulphate of ammonia at increased cost depending on the local price of oilcake.

The use of manures like animal meal or fish which supply phosphoric acid and nitrogen together would entail a change in the rotation at considerably increased cost at present prices.

Details cannot be fully considered here, but a rotation to suit soil and other local conditions, limited expenditure, and preferences of all kinds could be drawn up for each individual garden.

TOURING NOTES.

Eastern Dooars

BY

C. R. Harler, B.Sc., F.I.C.

Geography and Geology.

The tea district known as the Eastern Dooars extends from the Toorsa River in the West to the Sankosh River, which is the Assam boundary, in the East, a distance of about 35 miles. To the North the boundary is the Bhutan frontier which, except round Buxa, follows the line of the Himalayan foot-hills. The tea gardens are put out as near the hills as possible and seldom at a distance of more than eight miles from them. To the South, the tea lands give way to rice fields and the highly cultivated area of Cooch Behar.

Practically the whole district is covered with new alluvial deposits which vary from gravel near the hills to clay well away on the plains. At Buxa the Himalayas are fringed by low hills of the upper Tertiary period composed of red sandstone. These rocks are part of the Siwalik system extending along the entire southern flank of the Himalayas and encircling the Brahmaputra Valley to South Sylhet. In the Eastern Dooars they are known as Nahan sandstones and in Assam as the Tipam sandstones. Parts of Jaigon, Rungamattee, Phaskowa and Jainti are put out on the soil coming from the Nahan sandstones.

Behind these sedimentary rocks stand the metamorphic and crystalline rocks of the Himalayan zone. The rocks round Buxa have been called the Buxa series and consist of slates, quartzites and dolomites. The latter are mixtures of carbonates of magnesium and lime, giving rise to the alkaline deposits which are left by the rivers after flood.

An interesting observation was made by Mallet (Mem. Geol. Sur. Ind., Vol. XI, pt. I) who noticed that, proceeding up the

left bank of the Rydak, the first rock met is hornblende schist. About a couple of hundred yards away the Tertiary sandstone appears. There is no doubt that this schist belongs to the rock mass forming the Assam hills which are part of the Archaean system and older than the rocks of the Buxa series. The above outcrop is the one solitary point at which the Assam rocks have been observed at the foot of the hills between Nepal and the Goalpara district.

The Rivers.

The Rivers dominate the topography of the Eastern Dooars. The river courses may be divided into three sections. First there is the hill section where the water is confined within a deep gorge or defile and its course is more or less fixed. These gorges may become blocked by land slides following on *jhoom* cultivation and when such a block occurs immense volumes of water are held up which eventually break through and flood the plains. The detritus of the rivers having their source in the Bhutan hills consists largely of magnesia rocks which are alkaline and infertile for tea.

The second division of the course extends from the debouchure where the river first enters the plain till it runs in a fixed bed. It is here that boulders, stones and the coarser soil particles are deposited and into this porous bed much of the water percolates to appear again as springs some miles away.

The third division begins where the springs appear and this part is known as *terai* and carried dense forest and grass according to the degree of swampiness. It is on such sections that most of the tea gardens are put out. Lower down, the river bed becomes more defined and the banks are not only raised by floods but are artificially kept by cultivators. All the rivers eventually find their way circuitously to the Brahmaputra.

As the hills are left the soil becomes finer-grained. At Jainti the rock for making the permanent way to the Eastern Bengal Railway is collected from the river bed whilst fifteen miles away at Alipur Duar, bricks are made from the river banks. Flooding in the lower reaches of the rivers leaves a fertile deposit of fine silt and makes good jute land.

The courses of the Toorsa and the Rydak, like those of most of the rivers in the Dooars tend to move eastwards, but the Sankosh is moving westwards.

The Jungle.

The trees and type of jungle occurring in the Eastern Dooars change often with the general configuration of the land. Generally speaking there are three types of jungle. First there are the Sissoo (*Dalbergia sissu*) and Khaira (*Acacia catechu*) forests, common on old river beds. The Sisoo especially is able to thrive on poor sands.

The second type of jungle is Savannah, a free growth of Khagra (*Saccharum spontaneum*) interspersed with trees. On silty beds like that of the Kalchini district, where the water recedes to a great depth in the dry season and comes very near the surface during the rains, such jungle occurs. These areas usually make good tea lands for the surface wash is often so hindered by the Khagra that fine particles, rich in plant food, are given time to settle.

The third type of jungle is that occurring on the older soils which are usually the richest. Chilauni (*Schima wallichii*), Simul (*Bombax malabaricum*), Saj (*Terminalia tomentosa*), Sidha (*Lagerstraemia parviflora*), Udal (*Sterculia villosa*), Jamun (*Eugenia operculata*) and occasionally Toon (*Cedrela toona*) and Lampatia (*Duabanga sonneratioides*) occur. The Sal (*Shorea robusta*) is generally found on well drained soils intermediate between the richest and the poor sands. In the south of Buxa Forest the soil becomes too wet for the best growth of the Sal.

The Climate.

The climate of the Dooars differs considerably from that of Assam Valley. The table below shows the monthly average rainfall of Newlands Tea Estate as being typical of the rainfall for gardens close to the hills, together with that of Jalpaiguri as representing the rainfall of gardens some distance from the hills. In addition the rainfall for Tocklai, which may be taken as the average for Assam, is shown.

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Newlands	0·43	1·54	2·54	8·30	22·31	42·14	44·96	31·82	26·40	5·90	0 27	0·14	187·3
Jalpaiguri	0 48	0·39	1·47	3·63	11·84	25·89	29·57	24·81	22·65	4·78	0·14	0·07	125·76
Tocklai	0·56	1·45	3·51	9·18	9·35	14·43	15·82	14·24	10·64	4·33	0·65	0·38	79·18

The total rainfall of Buxa Cantonment which is in the hills at a height of about 2,000 feet, is 208·61 inches and that of Rungpore, well away in the plains, 75 miles from the hills, is 83·95 inches. Totals however give very little information with regard to the suitability of an area for tea planting. The distribution over the first and last three months of the year is the most important factor and it is here that the Assam climate scores over that of some parts of the Dooars. The distribution at Newlands over the critical six months from October to March is almost the same as that of Tocklai and the totals for these periods are almost the same—10·82 and 10·88 inches. At Jalpaiguri however the distribution is not nearly so good and the total is only 7·33 inches. In addition, the average maximum temperatures of Assam during the dry season are from 3°F to 5°F lower than those of the Dooars, another point in favour of the Assam Valley climate. The health and vigour of the tea in the Eastern Dooars is largely due to the fact that the soil naturally forms a good mulch which effectively conserves the moisture during the drought.

The heavy downpours experienced in the Dooars necessitate a different scheme of drainage from that followed in Assam where rarely more than an inch of rain falls in a day and shallow drains on clay soils effectively carry away the run-off waters. Much wider drains at closer intervals are required to cope with the volume of water precipitated on such heavy soils of the Sankosh Group of gardens than would be necessary on a similar soil in Assam.

An interesting climatic feature of the Dooars is the Gorge Winds which blow from the Himalayas in the evening from November to February. These winds flow in to take the place of the hot air rising from the plains and coming as they do from snowy regions, are comparatively cold and dry. On descending they are compressed and thereby warmed up and their relative dryness accentuated. In some respects these winds resemble the Föhn winds which blow warm and dry from the Alps into the Swiss Valley.

In the Dooars the lowest temperatures are often recorded in February. At Kalchini, temperatures as low as 38°F have been

registered in this month. The lowest temperature registered at Tocklai is 40°F.

The gardens of the Eastern Dooars may be conveniently considered in areas formed by rivers running generally north and south. To the extreme West lie Jaigon, Dalsingpara and the Hasimara gardens occupying a strip of land between the Toorsa and the Gabur Basra Rivers. The Kalchini district, which includes Rajabhat, Bhatkowa, Kalchini, Dima, Bhatpara, Mechpara and Chuapara, is on a silt bed of great depth between the Gabur Basra and the Raimatong-Dima Rivers. Separating Kalchini from the next sub-district is the Buxa Forest Reserve, stretching right to Phaskowa, a distance of over ten miles. Between the Reserve and the Rydak River are put out Phaskowa, Jainti and the Kartick gardens, differing widely accordingly to their soils but forming a convenient group from the geographical point of view. West of the Rydak and between that River and the Sankosh come Newlands, Kumargram and Sankos gardens.

The Hasimara Group.

From the north end of the Hasimara district to the south there is a complete change in soil. Jaigon, a garden whose boundaries march with the Bhutan frontier, is put out on a reddish soil which is actually part of the foothills and belongs to the Tertiary sandstone type of soil. On the Toorsa side of the garden there is a sheer drop of about twenty feet to the flood plain of the River. Situated as it is right at the angle between the Himalayas and the plains, Jaigon naturally has a wide range of soils varying from heavy clay to gravels which have been washed down in times of flood.

From Jaigon the land slopes gently away to the south although Dalsingpara is still on a bank well above the Toorsa River. The soil in this garden probably came from the adjacent hills and overlies the red soil.

The Hasimara Gardens were laid down mainly from the Toorsa River. Towards this river the soils are lightest. They get heavier further from the river and then lighter again as the area coming under the influence of the flood plain of the Gabur Basra is approached.

A great part of the district is a silt bed and to the south small rivers appear from the earth after having run under-ground for some miles.

The Kalchini Group.

The Kalchini gardens lie on a silt bed which was at one time Savannah and Khagra land. At the North end of the district the rivers disappear into the soil and appear again as springs in the south. In many places, below about a foot of soil, lies a layer of cheesy silt which is followed by a chocolate coloured loam. The roots of the bushes from such areas show good lateral development in the top foot which is followed by a bare tap root through the foodless silt, after which comes a second lateral development when the loam is entered. It has been noticed that plants often grow well for the first two years or so and then hang fire for a year only to come again with renewed vigour later on. These changes can be explained by a consideration of the alternate layers of good and poor soil.

Stony ridges, another evidence of fluviatile deposit, are common in the Kalchini district. In most cases such areas seldom pay for replanting but since they cannot be left to go into jungle a green crop should be put out on them.

The great advantage possessed by the soils of this district is that they are usually just fine-grained enough to retain moisture in the dry season yet are open enough to form a mulch naturally after the deep hoe. Physically, many of the soils are ideal and when once the tea is established it grows better than in most other districts.

Rungamattee is a garden put out on the hill slopes and is separated from the Kalchini group of gardens by the Pana and allied rivers which flow south-west to join the Gabur Basra system. From the soil point of view this garden is quite distinct from the others in the group but from the geographical stand-point it is conveniently considered here. In parts of the garden are stones and rubble overlying the red soil. At Pana, the out-garden, one section near the outer edge of a sweep of the River clearly shows that in flood the water had been over the land, and here silt overlies the heavier red soil.

When a soil is transported by washing, the various fractions are deposited according to the rate of flow of the stream which naturally depends on the slopes of the land. The fractions deposited by the water transportation of the red soils are seldom red in color. Redness in a soil comes with age.

The Phaskowa Group.

Phaskowa garden stands right at the foot of the mountains and much of the tea is planted on the area troubled by the tremendous rush of water which is inevitable from such a situation. The upper part of the garden consists of small hillocks of gravel and sand interspersed with pockets of fine sand and in the river beds of this area, schists, quartz and black and white marble are found. One section of the garden is at an elevation of 600 feet above the disturbed area and here the soil is red.

The lower part of the garden bordering on the road, and the garden of Chuniajhora are on a good lie of land benefiting from soil washed from higher up.

Jainti is planted out mainly on a tongue of reddish soil which stretches from the hills. Raina is a continuation south of the road. These soils are much older and somewhat heavier than the alluvium met a few miles further south. On one part of Jainti is an alkaline patch which will not grow tea. The soil here is new and is infertile partly from lack of humus and partly from magnesia deposits.

Rydak is a garden on a silty bed similar to that met in the Kalchini district. At Kartick some of the soils are extremely light but tea does well after it is established. In putting out tea on these light sands the element of luck is much more in evidence than on heavier soils, for a bad drought, or two years of drought before the bushes are well established, are sufficient to permanently put back the garden. Collar pruning young tea on such soils is not advisable unless it is carried out in June or July.

One section of Kartick is noteworthy on account of its alkaline soil. At one time a drain was made between the Turturi and Phaskowa Rivers and during periods of flooding the Phaskowa made this drain its new bed and joined the Turturi some distance

above the former junction. The area between the new and old Phaskowa beds is alkaline, yet unlike most alkaline soils met near the hills, it is apparently fertile and chemical analyses show it to be rich in plant food. It is probable that here the soil is not a new one but has gathered plant food and become acid through ages of washing only to be rendered alkaline by recent spill waters from the Phaskowa when in spate.

The Newlands Group.

These gardens extend from the Rydak to the Sankosh. The heavy black clay occurring in all of them suggests that much of the land here was once a swamp which suddenly stopped the water flowing from the hills and allowed the clay to settle. When the soil is not heavy it is generally loamy and easy to work.

The drainage problem here is a difficult one. Ordinary shallow, close drains would suffice for a heavy soil but in order to cope with the volume of water precipitated the drains must be wide. The percolation through such soils is almost nil as is demonstrated by the fact that when the drains are three rows apart, the middle row of tea often suffers from waterlogging. Trenching across the directions of the drains should do much good.

At Kumargram some trouble arises from spill and seepage water from the Dhumpara Forest. This is being obviated by the digging of a deep drain east and west at the north end of the garden.

North of the Dhumpara Reserve it is said that the soil becomes red and slopes gently to the foothills. Although it is generally considered that these red soils make good tea lands, the ideal situation will be found further from the hills where the soil is lighter.